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November 30, 1992

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REF: N00014-91-C-0222
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|---|---|---|
| Re: Contractor | : | Northeast Semiconductor, Inc. |
| Address | : | 767 Warren Road, Ithaca, NY 14850 |
| Req. No. | : | s405811srv02/17 APR |
| Contract No. | : | N00014-91-C-0222 |
| Report Date | : | November 30, 1992 |
| Report Title | : | 9th Monthly Technical Report |
| Period Covered | : | 10/01/92 through 10/30/92 |

Dear Dr. Schimitschek:

Northeast Semiconductor, Inc. encloses its Ninth Monthly Technical Report (Line Item #0002) pursuant to the provisions of contract Section B entitled, "Supplies or Services and Prices/Costs" for the period of November 1, 1992 through November 30, 1992.

**Innovative Techniques for the Production of Low Cost 2D Laser Diode Arrays**

## 1.0 OBJECTIVE

The primary objective of this program is to develop a low cost, high yielding methodology for processing, packaging and characterization of MBE grown two dimensional high power laser diode arrays. Projected increases in overall yield of AlGaAs diode lasers would reduce manufacturing cost from the current $10 to $20 per peak watt to below $3 per peak watt. Emphasis will be placed on innovative packaging techniques that will utilize recent advances in diamond heat sinking technology.

## 2.0 PROGRAM METHOD AND SCHEDULE

This program consists of four phases which will demonstrate reduced manufacturing cost and improved device performance of NSI's MBE laser diode arrays. The four phases listed below will result in milestones in processing, packaging, and testing along with delivery of the specified number of 5-bar laser arrays.

(i) Concept phase: Conceptual design and organization of this phase II program. NSI will utilize the current side cooled package to manufacture 5-bar laser diode arrays for base line evaluation. (Deliverables: 3 5-bar arrays.)

(ii) Backplane phase: Investigation of backplane cooling technologies that incorporate BeO, W/Cu and CVD diamond materials. This phase will also include the completion of room temperature photoluminescence development. (Deliverables: 5 5-bar arrays.)

(iii) Optimize Backplane phase: Investigate and optimize various backplane technologies. This will involve evaluating different packaging materials and processes pertaining to thick films, copper, direct bond copper to BeO, W/Cu and CVD Diamond. Feasibility and cost will be dominant factors. (Deliverables: 5 5-bar arrays.)

(iv) Liquid Cooled phase: The best proven backplane technology developed to date will be incorporated into a innovative liquid cooled assembly. Due to the numerous potential backplane schemes, this package type will be specifically designed to be compatible with the preferred backplane technology chosen. (Deliverables: 5 5-bar arrays.)

The following global issues not mentioned above will be investigated continuously throughout all four phases of this program:

(1) design and development of a mask set to increase processing and packaging yields,

(2) development and updating of MBE growth software,

(3) design and development of an in-house facet coating station,

(4) evaluation of different facet coating materials,

(5) development of automated tests,

(6) life test and burn-in development.

The master schedule for this program is shown in Table 1. Each phase will require wafer growth, processing, assembly and test. The schedule shows the estimated number of sample fabrications and tests, as well as the time of hardware deliverables and reports.

## 3.0 PROGRESS THIS PERIOD

### 3.1 Wafer Growths

Three laser structures and two calibration layers were grown at the beginning of November. Due to scheduled and unscheduled facility maintenance at the MBE laboratory, no further structures were grown. The maintenance involved re-routing the liquid $N_2$ and electrical supply to the MBE machine. Opportunity was also taken to refuel the Ga cell and inspect the remaining sources. The MBE facility is schedule to be functional by the second week of December.

### 3.2 Processing

Efforts this past month were focused on improving the facet coating yield. A failure mechanism identified last quarter pertained to p-side metalization encroaching over the emitting regions. This prompted several metalization experiments to reduce the amount of pliable Au needed for a solderable surface (results are listed in the fourth quarterly report). To further decrease the p-side metal defects, an experiment was performed to reduce damage caused by the repeated contact of bar facets to adjacent bars during the cleaving process. The standard cleaving procedure involves mounting the laser material on wafer grips and rolling the membrane over a steel rod to initiate the cleave. When the membrane is relaxed the bars tend to impact each other and press metalization and/or polyimide defects into the emitting regions. Therefore, upon cleaving the laser material, the membrane is clamped and not allowed to relax prior to dissolving. Inspection of the laser diode bars indicates a decrease in process related defects present in the emitting regions. In addition to the procedural change mentioned above, an extra cleaning step was introduced after bar loading of facet coating jig. This proved necessary due to the large number of particles introduced during the loading process. The cleaning procedure involved trichloroethane vapor bath followed by an acetone rinse and bakeout. Yield figures are currently being collected and initial results look encouraging.

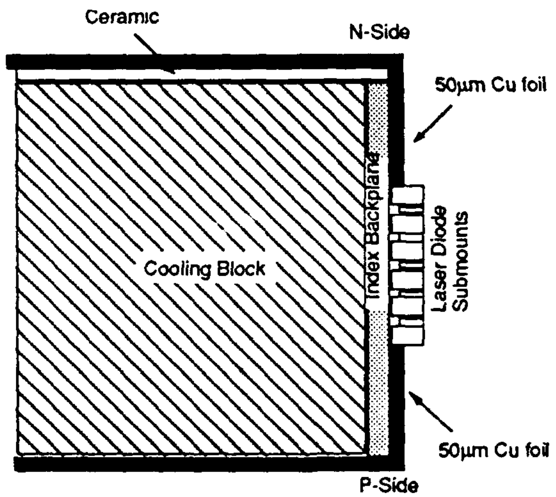
Two different quarter wafer sections, from recently grown material, are being processed utilizing the mask set designed for this program. One other partial section was also started with NSI's standard mask set serving as the control. Due to internal scheduling, the control sample finished ahead of the two mask qualification samples. Upon testing the control, it was discovered that the mesa etch was too shallow allowing lateral gain within the cavity. The two experimental pieces also suffer from this process deviation. Options are being considered to oxygen-plasma etch the polyimide off the two samples and re-etch the mesas.

### 3.3 Testing

Development work this past month was done on designing/fabricating thermal electric (TE) cooling systems for the life test racks. Constant variations in temperatures results in misleading interpretation of collected data. Due to the long durations, manpower expended, and importance of life testing, it is imperative to have strict control over the operating conditions. Work involved designing the heat spreader between the array and TE cooler, clamping for the entire assembly, and circuit design. Software and computer upgrades will also need to be performed.

### 3.4 Assembly and Packaging

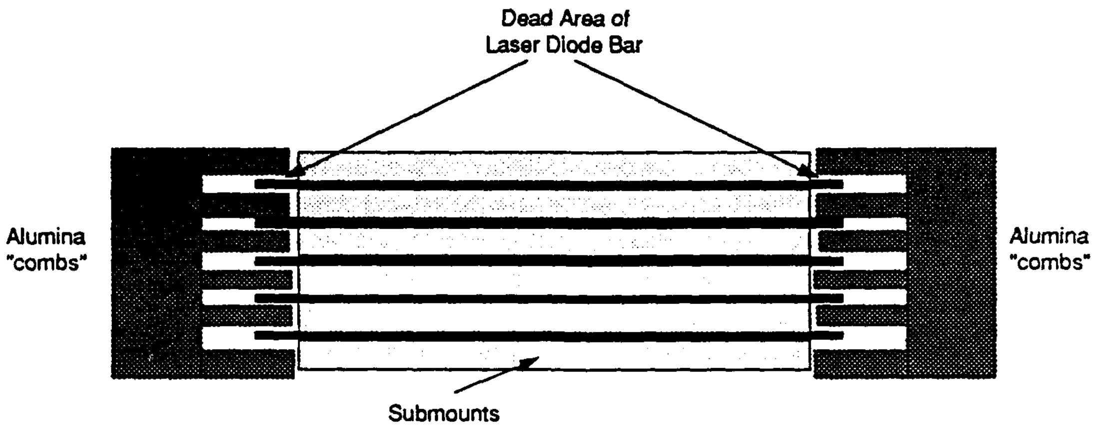
Packaging advances this past month included successfully making electrical contacts to the backplane multi-bar array. This was done by soldering 50µm thick Ni/Au plated copper ribbon to the front faces of the assembly. The p-side contact will be attached to the cooling stage and the n-side will be fastened to the top isolated by a ceramic as shown.






Difficulties are being experienced with the fabrication of the second set of deliverables for this program. These deliverables consist of five 5-bar backplane cooled laser diode arrays. Problems encountered are discussed in the following paragraphs.

The packaging strategy developed for the current set of deliverables involved loosely positioning the submount onto an indexed backplane. The submounts were positioned by an alumina comb structure that used the nonactive ends of the laser diode bars that extend out of the submount. The surface tension of the solder present on the backplane stripe self-aligned the submounts. The comb structure is showed below.




During and after assembly, the submounts were very fragile. Any force exerted on the end of the bars would cause damage to that particular submount. Possible solutions: (1) make guards on the side of the completed assembly (with cooling stage) or (2) Modify the comb structure to hold the submount and eliminate the fragile bar extensions. The first solution will make the overall package larger, more complicated, and more costly. The submounts themselves would still be fragile and a breakage prior to assembly would eliminate that submount from the stack. The second approach seems more logical and will produce a more robust package. Possible difficulties with this scheme pertain to wicking in the n-side contact which may bridge the ends and short the submount out. One other concern with holding the submounts instead of the laser bar is associated with the distance available from the rear facet to the submount/backplane interface. To reduce chance of failure at this point, the next set of submounts have been made 750µm wide instead of 570µ. Although this will increase the thermal path to the backplane, it will aid in the handling and cleaning steps. These submounts are currently on order.

Difficulties also arose due to the close melting points of the solders used for the p-side contact(70%In/30%Pb) 175°C and the backplane (100% In) 157°C. Submounts have been fabricated this past month with Au/Sn as the p-side solder material (approx. 280°C) on 80%W/20%Cu. These submounts have not yet been assembled onto a backplane.

Preparations for comparing indexed to solid backplanes have begun. Configurations currently being investigated utilize a step behind the rear facet such that the individual submounts can be compressed together. This would eliminate the need for the comb alignment structure mentioned above.

## 4.0 PLANS FOR DECEMBER

NSI's MBE facility is scheduled to be functional by the second week of December. Laser structures will be grown that can be utilized in the program for deliverables, mask evaluation, and process experimentation. Process experiments will continue to further increase facet coating yield. Developments will continue in construction of TE cooler systems for the life test facility.

Emphasis will be placed on successfully developing a 5-bar backplane cooled laser diode array. Submounts utilizing Au/Sn for the P-side solder joint will be assembled onto indexed backplanes with much lower melting point solders. New Cu submounts should arrive in mid-December that will use the alumina comb alignment fixtures that hold the submount instead of the laser diode bar.

Very truly yours,

Joseph A. Smart,
Principal Co-Investigator
Northeast Semiconductor, Inc.

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Encl: 1 Copy of 9th Monthly Technical Report

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| Department: Laser Product Line<br>Project(s): QHR Phase II<br>Contract #: N00014-91-C-0222 | KEY ○ Start Task ◇ Milestones △ Completion Date 1 ▽ Completion Date 2 | | | | | | | | | | | | Date : 30 November 1991<br>Prepared By: Geoffrey T. Burnham<br>Revised (shaded boxes): 30 September 1992 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PAGE 1 of 2 | 1991 | | | | | 1992 | | | | | | | | | | | | 1993 | | | | | | | |
| Milestones | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A |
| High Yield Epitaxial Growth | | | | | | | | | | | | | | | | | | | | | | | | | |
| System Qualification | ○ | | | | △ | | | | | | | | | | | △ | | | | | | | | | |
| Wafer Starts | | | | | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | |
| Review Incoming Inspection | ○ | | | | | △ | | | | | | | | | | | | | | | | | | | |
| Update Growth Software | ○ | | | | | | | | | | | | | | | | | | | | | | | △ | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wafer Processing | | | | | | | | | | | | | | | | | | | | | | | | | |
| Processing Starts | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| Develop Room Temp Pl. Test | ○ | | | | | △ | | | | | | | ▽ | | | | | | | | | | | | |
| Develop Facet Coating | ○ | | | | | | | | | | | | | | | | | △ | | | | | | △ | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| Packaging | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 - Bar Submounts | | | | 15 | 30 | 30 | 10 | 10 | 10 | 10 | 30 | 30 | 10 | 10 | 10 | 10 | 30 | 30 | 10 | 10 | 10 | 10 | 30 | 30 | |
| 5 - Bar Arrays | | | | | | | | | | | | | | | | | | | | | | | | | |
| Current | | | | | | | | 6 | | | | | | | | | | | | | | | | | |
| Cu Backplane | | | | | | | | | | | | | 10 | — | → | 10 | | | | | | | | | |
| CVD Diamond | | | | | | | | | | | | | | | | | | | 10 | | | | | | |
| EGW Cooled | | | | | | | | | | | | | | | | | | | | | | | | | 10 |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| Testing | | | | | | | | | | | | | | | | | | | | | | | | | |
| Develop Automated Tests | ○ | | | | | | | | | | | | | | | | | | | | | | | △ | |
| Life Tests / Burn - In | ○ | | | | | | | | | | | | | | | | | | | | | | | △ | |

TABLE 1. MASTER SCHEDULE FOR SBIR PHASE II
CONTRACT NO. N00014-91-C-0222

Department: Laser Product Line
Project(s): ONR Phase II
Contract # : N00014-91-C-0222

KEY ○ Start Task ◇ Milestones △ Completion Date 1 ▽ Completion Date 2

Date : 30 November 1991
Prepared By: Geoffrey T. Burnham
Revised (shaded boxes): 30 September 1992

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| Milestones (Continued) | 1991 | | | | | 1992 | | | | | | | | | | | | 1993 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A |
| Testing (continued) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 - Bar Arrays | | | | | | | | ○ | | | | | | | | | | | | | | | | | △ |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| Deliverables | | | | | | | | | | | | | | | | | | | | | | | | | |
| Reports | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monthly | | | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | |
| Quarterly | | | | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | |
| Final | | | | | | | | | | | | | | | | | | | | | | | | | △ |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 - Bar Arrays | | | | | | | | | | | | | | | | | | | | | | | | | |
| Current | | | | | | | | 3 | | | | | | | | | | | | | | | | | |
| Cu Backplane | | | | | | | | | | | | | 5 | | → | 5 | | | | | | | | | |
| CVD Diamond | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| EGW Cooled | | | | | | | | | | | | | | | | | | | | | | | | | 5 |